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Workability Performance of Fresh Concrete Incorporated with GSA, GGBS and WF

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ABSTRACT

The concrete is the most widely used building materials in the world throughout for the construction of infrastructure and other structures. The concrete is the second widely used substance on the earth next to water. The concrete is the composite homogeneous materials, which is commonly consists of cement, fine aggregate, coarse aggregate and water. Among the various materials, the cement is most important materials in the preparation concrete. It will provide bond strength to concrete by binding the fine and coarse aggregate with each other due to chemical reaction developed by hydration of water. At the same time, the cost of cement is very high when compared to other materials used in concrete. On the other hand, the manufacturing of cement in large quantity is producing environmental pollution by emitting the CO2 content in huge volume to the environment. These two issues are induced the Civil Engineers to find the alternative binding materials for the better replacement of cement. In this research work, the locally available agricultural and industrial waste materials are used for the partial replacement of cement. In this present study, the agricultural waste used is Groundnut Shell Ash (GSA) and industrial waste material is Ground Granulated Blast-furnace Slag (GGBS). The GSA is an ash obtained after burning the groundnut shell at high temperature in the kiln and the GGBS is a non-metallic waste material available from iron industry. Hence the utilization of these waste materials without a harmful effect on nature has an important role for the manufacturing of concrete in conduction industries. In the present work, it is proposed to examine the workability performance study of concrete with partially replacing the cement with GSA, GGBS and WF with and without addition of super plasticizer. The slump test and compaction factor test were performed to evaluate the workability characteristics of fresh concrete for M20 mix grade.

KEYWORDS: *GSA, GGBS, WF, Slump and Compaction factor*

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1. INTRODUCTION:

In present situation, huge volume of waste by-product materials is directly discarded on earth without doing any treatment. The waste by-product materials are groundnut shell, coconut shell, cashew nut shell, maize combs, saw dust, GGBS, fly ash, rice husk, etc. These waste materials are dumped on the land is seriously producing environmental pollution. Large volumes of waste materials which are disposed on the land with minor effective method of waste recycling alone. Some of these discarded waste materials are not fully decayed and thus create diseases to the people [1]. The ashes obtained from the waste by-product materials, like, groundnut shell, coconut shell, cashew nut shell, maize combs, saw dust, GGBS, rice husk and fly ash have been used as pozzolanic materials. These secondary cementing materials help to decrease the permeability of concrete by changing their pore structure and thus improve the workability and durability [2]. The groundnut shell is regularly used to cook by burning or discarded or left to decompose naturally. It will generate trouble to the people and environment, when it is dumped on the land without doing any recycling process [3-4].

Hence, it is planned to utilize the by-product waste material of groundnut shell in the form of ash for the replacement of cement for the concrete preparation. The utilization of groundnut shell ash will safeguard the environment and people from serious environmental hazards and to promote the economy in the construction industry by controlling the cost of construction. The compressive and tensile strength of concrete is decreased when the replacement level of GSA is increasing from 8%. Also, the workability of concrete is decreased while increasing the GSA replacement level [5].

Therefore, it is decided to incorporate one more cementing materials which obtained from iron industries, that is, Ground Granulated Blast Furnace Slag (GGBS) in order to enhance the strength and workability performance of concrete blended with GSA. The GGBS is a by-product obtained from blast-furnace of iron ore industries [6-7]. It contains large amount of silicates and alumina silicates of calcium. It is an excellent replacement for OPC due to it comprise of essential chemical components such as lime, calcium sulphate and alkalies to stimulate the slag with cement [8-10]. The substitute level of GGBS is varying from 20 to 50% at the interval of 5% by weight of cement along with GSA replacement varying from 6 to 10%. M20 concrete mix with water cement ratio 0.55 is adopted in this study. The result demonstrates that the cube compression strength

is increased when the GGBS is replaced with GSA and it is suddenly decreased when the GGBS replacement level is more than 35%. But there is no any enhancement in the splitting tension and prism flexural strength of concrete when the cement is blended with GSA and GGBS. On other side the workability of concrete is improved for all specimens when the cement is substituted with both GSA and GGBS.

Then, it is decided to enhance the splitting tensile and prism flexural strength of concrete by incorporating fibre. Different types of fibres are available in the market as artificial fibres and natural fibres. Carbon fibre, steel fibre, metallic fibre, boron fibre, polypropylene fibre, glass fibre etc are categorised as artificial fibre and bamboo fibre, banana fibre and wool fibre are called as natural fibre [11-12]. The substitution of randomly distributed fibres to cement based materials can increase their fracture toughness, ductility and impact resistance [13]. The wool fibres taken from Scottish sheep has been used in the soil to obtain the soil matrix. The amount of wool fibre used is 0.25% to 0.5% by weight of soil. Tests showed that addition of alginate increases compression strength from 2.23 to 3.77 MPa at 69%. The addition of wool without alginate (maybe due to its hard workability) does not improve performance so much: adding only wool also increases compression strength at 37%, from 2.23 to 3.05. But the addition of both, wool and alginate improves moderately (doubles) ERROL soil resistance up to 4.44 MPa. Better results were obtained with a lower quantity of wool [14]. Hence, the wool fibre taken from sheep (WF) from 0.1% to 0.5% is used in this research work along with GSA and GGBS to enhance the tensile and flexure strength of concrete.

2. MATERIALS AND THEIR PROPERTIES

The basic materials used in the research work are: Ordinary Portland Cement (OPC), Fine Aggregate, Coarse Aggregate, Groundnut Shell Ash (GSA), Ground Granulated Blast Furnace Slag (GGBS), Wool Fibre (WF), and Super plasticizer.

2.1. Fine Aggregate

Size: passing through 4.75mm and retaining on 0.75 micron
Specific gravity: 2.67
Fineness modulus: 2.9
Unit weight: 1558kg/m^3
Type: River Sand Grading zone – II (angular shape)

2.2. Coarse Aggregate

Size: passing through 20mm and retaining on 10mm sieve.
Specific gravity: 2.74
Unit weight: 1684kg/m^3
Type: Crushed granite with angular shape

2.3. Cement

Specific gravity: 3.13
Fineness: 312m^2/kg
Consistency: 31%
Brand: OPC 43 grade

2.4. GSA

Specific gravity: 1.93
Size of GSA: 10 to 75µ
Bulk density: 1090kg/m^3
Fineness: 329m^2/kg

2.5. GGBS

Specific gravity: 2.75
Size of GGBS: 10 to 45µ
Bulk density: 1172kg/m^3
Fineness: 342m^2/kg

2.6. Water:

Ordinary potable water free from impurities with pH value 6.9 was used.

2.7. Super Plasticizer:

Product name: Conplast SP430
Appearance: Brown liquid
Specific gravity: 1.2
pH value: 7 to 8

3. MIX DESIGN

3.1. Mix ratio of concrete

The mix design for concrete (M20) with the water-cement ratio of 0.55 were adopted according to IS 10262-2009 and the details of mix design is listed in Table 1. A very lesser volume of Super plasticizer at 1% volume on weight of cement has been used to produce good workability. The proportions of fine aggregate, coarse aggregate, and water are fixed constant throughout the research work. The cement is only replaced with GSA and GGBS. Also the WF is used to increase the tensile strength of concrete.

Table 1: Mix ratio of concrete

Sl. No.	Materials	Mix Proportions	
		In weight	In parts
1	Cement	344.68kg	1
2	Fine Aggregate	616.97kg	1.79
3	Coarse Aggregate	1158.12kg	3.36
4	Water	189.57lit	0.55

3.2. Mix Proportions

In this research work, totally 12 mixes were casted to forecast the slump and compaction factor value by replacing the cement with GSA, GGBS and WF. The specimen prepared without replacement of waste materials is designated as control specimen (C). The specimens (P1 to P5) casted by replacing the cement using GSA from 2% to 10%, the specimens (P6 to P8) casted by replacing the both cement using GSA from 6% to 10% and GGBS from 20% to 50% and the specimens (P9 to P12) casted by replacing the all the waste materials, such as, cement using GSA from 6% to 10%, GGBS from 20% to 50% and WF from 0.1% to 0.5%. The details of specimens prepared for workability study of concrete are shown in Table 2.

Table 2: Mix proportions for Workability study

S. No.	Sample ID	Cement (%)	GSA (%)	GGBS (%)	WF (%)
1	C	100	0	0	0
2	W1	98	2	0	0
3	W2	96	4	0	0
4	W3	94	6	0	0
5	W4	92	8	0	0
6	W5	90	10	0	0
7	W6	74	6	20	0
8	W7	57	8	35	0
9	W8	40	10	50	0
10	W9	73.9	6	20	0.1
11	W10	56.5	8	35	0.3
12	W11	39.5	10	50	0.5

4. RESULTS AND DISCUSSIONS:

4.1. Slump test on fresh concrete:

The workability of fresh concrete has measured quickly by performing the slump test. The slump test is the direct method used to assess the workability of fresh concrete in

both laboratory and at the site in accordance with IS: 1199 code provisions. A slump cone has 200mm diameter at bottom, 100mm diameter at the top and 300mm height. The interior surface of the slump cone was thoroughly cleaned by oil. The mould was filled with fresh concrete in three layers; each layer is approximately 1/3 of its height. Each layer was rodded using 16mm diameter tamping rod with 25 blows. After the compaction is over at the top layer, the slump cone was removed slowly and carefully from its position along vertical direction. The compacted concrete will collapsed considerably. The vertical height difference between the top of the mould and highest point of collapsed concrete was measured. This difference in vertical height is considered as slump value of fresh concrete. The slump is measured in terms of mm.

The workability performance of fresh concrete was found out using Slump cone test in accordance with IS 1199 code provision on the site. The slump cone test is the most popular, generally accepted field test because of the simple test procedure and simplicity of the equipment. This test identifies the performance of a compactly packed concrete cone under the stroke of gravitational forces. The slump values of fresh concrete for various mix proportions with and without super plasticizer are shown in Table 3.

The slump value of the fresh concrete for the control sample (C) was 33mm when the super plasticizer added with fresh concrete and it was 29mm for plain fresh concrete without super plasticizer. The samples W1, W2, W3, W4 and W5 are the only replacement of cement using GSA at 2%, 4%, 6%, 8% and 10% respectively. In this category, the slump values were decreased for all the samples than that of control sample (C) when it is added with and without super plasticizer. But the slump values were improved for all the samples (W1, W2, W3, W4 and W5) by adding the super plasticizer.

The samples W6, W7 and W8 are replaced with both GSA (from 6% to 10%) and GGBS (from 20% to 50%) for cement. In this category, the slump values for all the samples (W6, W7 and W8) were higher than that of control sample when it is added with and without super plasticizer. It was examined that, the maximum slump value was obtained when the cement is replaced with 10% of GSA and 50% of GGBS were 38mm and 36mm for the addition of super plasticizer and without addition of super plasticizer respectively. It was also observed that the slump values were improved for all the samples (W6, W7 and W8) by adding the super plasticizer.

The samples W9, W10 and W11 are replaced with all the waste materials, such as, GSA (from 6% to 10%), GGBS (from 20% to 50%) and WF (from 0.1% to 0.5%) for cement. In this category, the slump values for all the samples (W9, W10 and W11) were lower than that of control sample (C) when it is added with and without super plasticizer. It was noticed that the slump values were improved for all the samples (W9, W10 and W11) by adding the super plasticizer. The variations of slump values for the fresh concrete are shown in Figure 1.

Table 3: Slump and Compaction factor value for fresh concrete

Sample ID	Slump in mm		Compaction Factor	
	With Super Plasticizer	Without Super Plasticizer	With Super Plasticizer	Without Super Plasticizer
C	33	29	0.85	0.83
W1	31	27	0.84	0.82
W2	29	25	0.82	0.80
W3	27	22	0.81	0.79
W4	26	20	0.80	0.78
W5	24	19	0.77	0.76
W6	36	32	0.87	0.84
W7	37	34	0.89	0.86
W8	38	36	0.92	0.90
W9	27	22	0.83	0.81
W10	29	24	0.85	0.82
W11	31	27	0.87	0.84

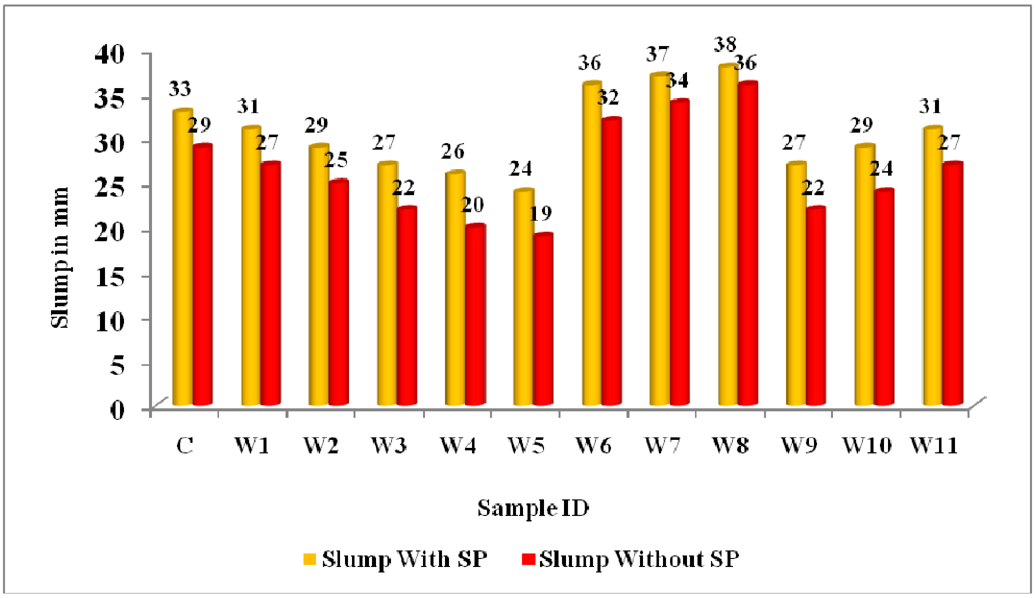

Figure 1: Variations of slump value of fresh concrete for different mixes

4.2. Compaction factor test on fresh concrete:

The compaction factor test is an important test which is used to determine the workability of fresh concrete in the laboratory. The ratio of weight of partially compacted concrete to fully compacted concrete is called as compaction factor. The compaction factor test is mainly used for fresh concrete which have little workability for which slump test is not precise. This apparatus mainly consists of trowels, 152mm long hand scoop, 16mm diameter and 610mm long steel rod and a weighing balance. The following steps are to be followed for compaction factor test.

- Place the fresh concrete sample smoothly in the upper hopper to its rim using the hand scoop and level the surface of concrete. Then cover the cylinder. Then Open the door which is available at the bottom of the upper hopper. Then allow to fall the fresh concrete into lower hopper. Push the concrete sticking on its sides smoothly using the steel rod.
- Next unlock the door which is available at the bottom of the lower hopper and allow the concrete to fall into the cylinder place at the bottom of lower hopper.
- Remove the excess of concrete over the top level of cylinder using trowels and level the surface of concrete. Clean the outside surface of the cylinder.
- Find the weight of empty cylinder and it is taken as W. Measure the weight of the cylinder with concrete. This weight is taken as the weight of partially compacted concrete **(W1).**
- Clean the cylinder and empty it. Then refill it with the same fresh concrete in layers approximately 50mm height, each layer being greatly compacted using the steel rod to obtain full compaction. Level the top surface of concrete.
- Weigh the cylinder with fully compacted concrete. This weight is taken as the weight of fully compacted concrete (**W2**). Finally calculate the compaction factor value of the fresh concrete using the following formula. The Compaction factor values may ranges from 0.7 to 0.95.

Compaction Factor Value = $\frac{(W1 - W)}{(W2 - W)}$

The workability performance of fresh concrete was determined using compaction factor test in the laboratory. It is the most accepted and well popular laboratory test. The compaction factor value of fresh concrete for various mix proportions are also shown in Table 3.

The compaction factor value of the fresh concrete for the control sample (C) is 0.85 when the super plasticizer added with fresh concrete and it was 0.83 for plain fresh concrete without super plasticizer. The samples W1, W2, W3, W4 and W5 are the only replacement of cement using GSA at 2%, 4%, 6%, 8% and 10% respectively. In this category, the compaction factor value was decreased for all the samples than that of control sample (C) when it is added with and without super plasticizer. But the compaction factor values were improved for all the samples (W1, W2, W3, W4 and W5) by adding the super plasticizer.

The samples W6, W7 and W8 are replaced with both GSA (from 6% to 10%) and GGBS (from 20% to 50%) for cement. In this category, the compaction factor values for all the samples (W6, W7 and W8) were higher than that of control sample (C) when it is added with and without super plasticizer. It was examined that, the maximum compaction factor value was obtained when the cement is replaced with 10% of GSA and 50% of GGBS were 0.92 and 0.90 for the addition of super plasticizer and without addition of super plasticizer respectively. It was also observed that the compaction factor values were improved for all the samples (W6, W7 and W8) by adding the super plasticizer.

The samples W9, W10 and W11 are replaced with all the waste materials, such as, GSA (from 6% to 10%), GGBS (from 20% to 50%) and WF (from 0.1% to 0.5%) for cement. In this category, the compaction factor values for all the samples (W9, W10 and W11) were lower than that of control sample (C) when it is added with and without super plasticizer. It was noticed that the compaction factor values were improved for all the samples (W9, W10 and W11) by adding the super plasticizer. The variations of compaction factor values for the fresh concrete are shown in Figure 2.

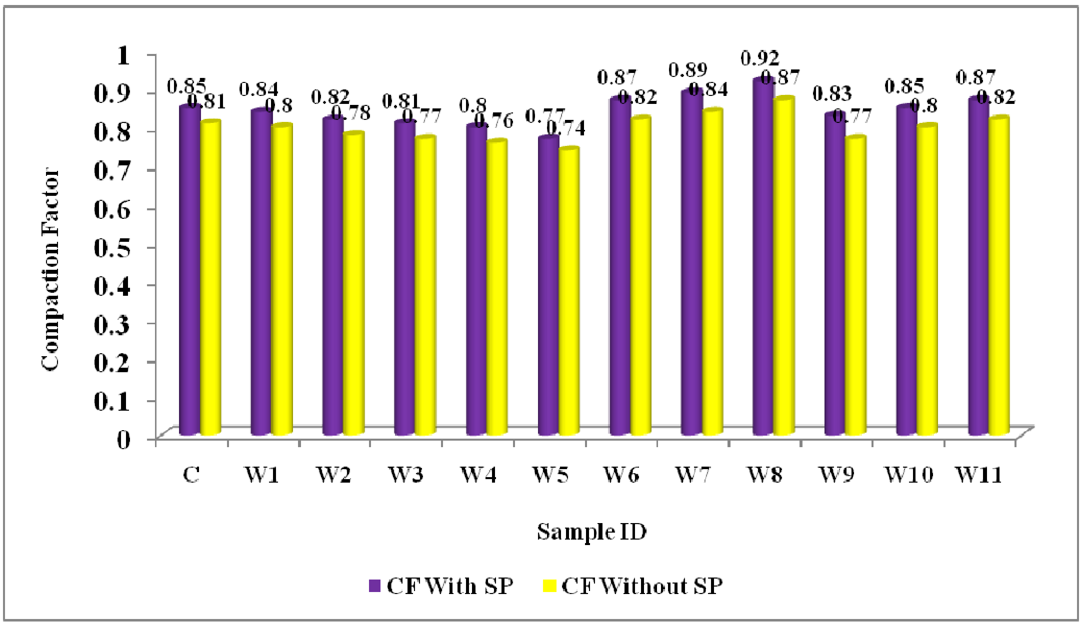

Figure 2: Variations of Compaction Factor value of fresh concrete for different mixes

5. CONCLUSION:

The following conclusions were made after conducting the slump test and compaction factor test on concrete to determine the workability of fresh concrete.

- The slump values and compaction factor values were decreased for all the samples (W1, W2, W3, W4 and W5) than that of control sample (C) when it is added with and without super plasticizer.
- The slump values and compaction factor values for all the samples (W6, W7 and W8) were higher than that of control sample when it is added with and without super plasticizer. The maximum slump value was obtained when the cement is replaced with 10% of GSA and 50% of GGBS were 38mm and 36mm with the addition of super plasticizer and without addition of super plasticizer respectively. The maximum compaction factor value was obtained when the cement is replaced with 10% of GSA and 50% of GGBS were 0.92 and 0.90 with the addition of super plasticizer and without addition of super plasticizer respectively.
- The slump values and compaction factor values for all the samples (W9, W10 and W11) were lower than that of control sample (C) when it is added with and without super plasticizer.
- It was noticed that the slump values and compaction factor values was improved for all samples when the addition of super plasticizer.

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